

NASA/TM—2005-213418



Launch Vehicle Communications

Bryan Welch and Israel Greenfeld
Glenn Research Center, Cleveland, Ohio

January 2005

The NASA STI Program Office . . . in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program Office plays a key part in helping NASA maintain this important role.

The NASA STI Program Office is operated by Langley Research Center, the Lead Center for NASA's scientific and technical information. The NASA STI Program Office provides access to the NASA STI Database, the largest collection of aeronautical and space science STI in the world. The Program Office is also NASA's institutional mechanism for disseminating the results of its research and development activities. These results are published by NASA in the NASA STI Report Series, which includes the following report types:

- **TECHNICAL PUBLICATION.** Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA's counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.
- **TECHNICAL MEMORANDUM.** Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.
- **CONTRACTOR REPORT.** Scientific and technical findings by NASA-sponsored contractors and grantees.

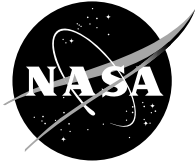
- **CONFERENCE PUBLICATION.** Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.
- **SPECIAL PUBLICATION.** Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.
- **TECHNICAL TRANSLATION.** English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services that complement the STI Program Office's diverse offerings include creating custom thesauri, building customized databases, organizing and publishing research results . . . even providing videos.

For more information about the NASA STI Program Office, see the following:

- Access the NASA STI Program Home Page at <http://www.sti.nasa.gov>
- E-mail your question via the Internet to help@sti.nasa.gov
- Fax your question to the NASA Access Help Desk at 301-621-0134
- Telephone the NASA Access Help Desk at 301-621-0390
- Write to:
NASA Access Help Desk
NASA Center for Aerospace Information
7121 Standard Drive
Hanover, MD 21076

NASA/TM—2005-213418



Launch Vehicle Communications

Bryan Welch and Israel Greenfeld
Glenn Research Center, Cleveland, Ohio

National Aeronautics and
Space Administration

Glenn Research Center

January 2005

Acknowledgments

Many thanks to Dr. Roberto Acosta and Dr. Obed Scott Sands for discussion and insight in obtaining resources for phased array antennas and proper calculation techniques used in this analysis.

This report is a formal draft or working paper, intended to solicit comments and ideas from a technical peer group.

This report contains preliminary findings, subject to revision as analysis proceeds.

Trade names or manufacturers' names are used in this report for identification only. This usage does not constitute an official endorsement, either expressed or implied, by the National Aeronautics and Space Administration.

Available from

NASA Center for Aerospace Information
7121 Standard Drive
Hanover, MD 21076

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22100

Available electronically at <http://gltrs.grc.nasa.gov>

Launch Vehicle Communications

Bryan Welch and Israel Greenfeld
National Aeronautics and Space Administration
Glenn Research Center
Cleveland, Ohio 44135

Abstract

As the National Aeronautics and Space Administration's (NASA) planning for updated launch vehicle operations progresses, there is a need to consider improved methods. This study considers the use of phased array antennas mounted on launch vehicles and transmitting data to either NASA's Tracking and Data Relay Satellite System (TDRSS) satellites or to the commercial Iridium, Intelsat, or Inmarsat communications satellites. Different data rate requirements are analyzed to determine size and weight of resulting antennas.

Introduction

Launch vehicle (LV) operations are always in need of enhanced communications capability to keep pace with growing requirements. To support operations at more than one launch pad at a time and to improve safety, there is a growing need for larger amounts of data, including video, to pass between the LV/payload and launch control.

Currently, communication needs are met by various types of dish antennas. By their nature, dish antennas are limited to one-on-one links and require mechanical slewing to maintain pointing. To support multiple operations and to seamlessly switch from one launch pad or launch vehicle to another—even launch pads at large geographical separations—and to readily track launch vehicles as they ascend into orbit, mechanically driven dishes present a limiting situation. The limitations are in both covering launch pads that are beyond line of sight and serving multiple links.

A possible mitigation of these limitations could be met by employing phased array antennas transmitting through communications satellites. This paper assesses whether commercial or government communications satellite systems could provide launch vehicles with Megabit per second (Mbps) data rate capabilities using phased array antennas. The considered data rates in this paper were 1, 5, and 10 Mbps. For the purposes of this study, the satellite systems can be in Low Earth Orbit (LEO), Medium Earth Orbit (MEO), or Geosynchronous Earth Orbit (GEO), and can operate in L, S, Ku, or Ka-bands.

It is noted that this study merely attempts a high-level assessment and certain specific considerations need to be explored more fully before an actual decision of usage can be made.

Satellite Systems and Study Assumptions

The communications satellite systems used in this study are three commercial and one government systems. The commercial systems are the LEO Iridium© [1] and the GEO Inmarsat© [2] and Intelsat© [3]. The government system is the GEO Tracking and Data Relay Satellite System (TDRSS) [4].

Satellite system parameters used in this study are the frequency band and satellite Gain/Temperature Ratio (G/T). The parameters used are shown below in table 1.

TABLE 1.—FREQUENCY AND G/T PARAMETERS

Satellite	Frequency (GHz)	G/T (dB/K)
Iridium	1.623	-16.315
Inmarsat	1.635	-11.5
Intelsat	14.25	9.0
TDRS-S	2.25	9.50
TDRS-Ku	15.003	24.40
TDRS-Ka	27.50	26.50

To conduct this study, certain values for basic antenna parameters needed to be assumed. Below is the list of assumptions.

- 3 dB link margin
- 1e-9 Bit Error Rate
- 3 dB of additional losses
- Radiating element spacing of $0.75 * \lambda$
- 20 lbs. per square foot of array
- QPSK modulation
- No error coding
- 60° scan angle allowed (-4.5 dB Scan Loss)
- Patch radiating elements with 3 dB Gain
- Element DC power of 200 mW
- SPA efficiency of 20 percent
- Power supply efficiency of 80 percent

Study Results

Based on the assumptions listed above, this study calculated the number of elements required to close the link, the length of a square array that results from that minimum number of elements, and the resulting weight for the array. Table 2 shows the resulting sizes of arrays that would be required to support data rates of 1, 5, or 10 Mbps for the various communications satellite systems.

TABLE 2.—LENGTH AND WEIGHT COMPARISONS – SINGLE PHASED ARRAY ANTENNA

Satellite System (Frequency Band)	1 Mbps		5 Mbps		10 Mbps	
	L (in)	W (lb)	L (in)	W (lb)	L (in)	W (lb)
Iridium (L)	52.66	386.08	79.90	888.77	96.24	1289.54
Inmarsat (L)	166.03	3828.79	241.83	8122.61	290.56	11725.67
Intelsat (Ku)	17.19	41.02	25.26	88.64	30.23	126.94
TDRS (S)	41.97	244.60	61.64	527.66	73.44	749.09
TDRS (Ku)	6.88	6.58	10.42	15.09	12.19	20.65
TDRS (Ka)	4.40	2.69	6.65	6.15	7.94	8.76

This study also looked at three possible launch vehicles, namely Delta [5], Atlas [6], and Titan [7]. Based on LV diameter and the determined length of the arrays, a quick analysis was performed to decide whether the launch vehicle's dimension could support three arrays. Given a limitation of a 60° array scanning angle, three arrays are required to obtain full 360° coverage. The assumption was that all three arrays would lie along only one circle. Table 3 below, ascertains whether three phased arrays could possibly fit on the given LV (YES or NO decision), and what the combined weight of the three arrays would be, for the three data rates and for the six communications satellites cases.

TABLE 3.—LAUNCH VEHICLE ARRAY ACCOMMODATION (YES/NO)/TOTAL WEIGHT (LBS)

Satellite	Rocket	1 Mbps	5 Mbps	10 Mbps	1 Mbps	5 Mbps	10 Mbps
Iridium	Delta	YES	YES	YES	1158.25	2666.31	3868.63
	Atlas	YES	YES	YES	1158.25	2666.31	3868.63
	Titan	YES	YES	YES	1158.25	2666.31	3868.63
Inmarsat	Delta	NO	NO	NO	-----	-----	-----
	Atlas	NO	NO	NO	-----	-----	-----
	Titan	NO	NO	NO	-----	-----	-----
Intelsat	Delta	YES	YES	YES	123.07	265.91	380.82
	Atlas	YES	YES	YES	123.07	265.91	380.82
	Titan	YES	YES	YES	123.07	265.91	380.82
TDRS-S	Delta	YES	YES	YES	733.80	1582.97	2247.26
	Atlas	YES	YES	YES	733.80	1582.97	2247.26
	Titan	YES	YES	YES	733.80	1582.97	2247.26
TDRS-Ku	Delta	YES	YES	YES	19.74	45.27	61.95
	Atlas	YES	YES	YES	19.74	45.27	61.95
	Titan	YES	YES	YES	19.74	45.27	61.95
TDRS-Ka	Delta	YES	YES	YES	8.06	18.44	26.27
	Atlas	YES	YES	YES	8.06	18.44	26.27
	Titan	YES	YES	YES	8.06	18.44	26.27

Conclusions

This study is a high level look at the possibility of using phased array antennas, transmitting through communications satellites, to provide higher data rate capabilities to support launch vehicle operations. Given this, specific decisions on whether a communications satellite system and launch vehicle combination makes sense will require more in-depth study. This study merely determines whether the notion of phased arrays, communications satellites systems, and various launch vehicles makes enough sense to warrant further study.

On the basis of this study, size and weight requirements for phased array antennas yield values that in some cases might be practical. This study shows that TDRS-Ka yields the minimum size and weight for the necessary phased arrays, but other communication satellite systems might be acceptable for certain launch vehicle operations. On the other hand, the resulting weights for Iridium and TDRS-S antennas preclude their practical use given the large weight penalty.

Another consideration is using less than three antennas. Scenarios that might allow this assume fixed launch azimuths and trajectory profiles that remain in view of the communication satellites. Specific cases require detailed analysis of the geometry of the trajectory profile with the communication satellites.

However, this paper limits itself to low weight results given the weight penalties associated with launch vehicle operations. Based on these results, there is reason to think that future higher data rate communications could be supplied via phased array antennas mounted on launch vehicles.

References

- [1] Iridium Satellite LLC, http://www.iridium.com/corp/iri_corp-understand.asp, February, 2004.
- [2] Satellite Encyclopedia, http://www.tbs-satellite.com/tse/online/prog_inmarsat.html, February, 2004.
- [3] Satellite Encyclopedia, http://www.tbs-satellite.com/tse/online/prog_intelsat.html, February, 2004.
- [4] NASA, <http://msp.gsfc.nasa.gov/tdrss/>, February, 2004.
- [5] Spaceline, Inc., <http://spaceline.org/rocketsum/delta-program.html>, February, 2004.
- [6] Spaceline, Inc., <http://spaceline.org/rocketsum/atlas-program.html>, February, 2004.
- [7] Spaceline, Inc., <http://spaceline.org/rocketsum/titan-program.html>, February, 2004.

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE January 2005		3. REPORT TYPE AND DATES COVERED Technical Memorandum
4. TITLE AND SUBTITLE Launch Vehicle Communications			5. FUNDING NUMBERS WBS-22-041-40-99	
6. AUTHOR(S) Bryan Welch and Israel Greenfeld				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) National Aeronautics and Space Administration John H. Glenn Research Center at Lewis Field Cleveland, Ohio 44135-3191			8. PERFORMING ORGANIZATION REPORT NUMBER E-14942	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) National Aeronautics and Space Administration Washington, DC 20546-0001			10. SPONSORING/MONITORING AGENCY REPORT NUMBER NASA TM-2005-213418	
11. SUPPLEMENTARY NOTES Responsible person, Bryan Welch, organization code RCI, 216-433-3390.				
12a. DISTRIBUTION/AVAILABILITY STATEMENT Unclassified - Unlimited Subject Category: 32 Available electronically at http://gltrs.grc.nasa.gov This publication is available from the NASA Center for AeroSpace Information, 301-621-0390.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) As the National Aeronautics and Space Administration's (NASA) planning for updated launch vehicle operations progresses, there is a need to consider improved methods. This study considers the use of phased array antennas mounted on launch vehicles and transmitting data to either NASA's Tracking and Data Relay Satellite System (TDRSS) satellites or to the commercial Iridium, Intelsat, or Inmarsat communications satellites. Different data rate requirements are analyzed to determine size and weight of resulting antennas.				
14. SUBJECT TERMS TDR satellites; Iridium network; Intelsat satellites; Inmarsat satellites; Satellite antennas; Antenna arrays; Phased arrays; Launch vehicles			15. NUMBER OF PAGES 9	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT	

